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Vertical Greening Façade as Passive Approach in Sustainable Design

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Abstract

To overcome the excessive heat in tropical climate countries during the day, the types of skin or façade play a vital role in regulating the temperature and the amount of heat transmission in a building. This research was carried to evaluate the percentage of temperature reduction of two building samples, one with “vertical greening” and one without. The result proved that the temperature reduction of the building with the green façade system is higher than the building without the green façade system. Therefore, it justifies that Vertical Greening Façade does act as an acceptable passive approach for sustainable design.

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Keywords: Façade; vertical greening; passive approach; sustainable design

1. Introduction

Green architecture is one of the many ways to reduce the impact of construction of a new building on nature. The term green architecture is not just by preserving and conserving the trees on site but can also be implemented as part

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of the buildings component. One of the ways to implement nature on architecture is by using the 'breathing walls' on facade or what we call as vertical greenings.

Vertical greening façade is an exterior wall that is planted with plants mainly used for aesthetic and ecological purpose. To create the vertical greening facade, the plant must be of certain characters and the wall or support structure must be occupied with soil and water system. Usually, the plant that is used for the vertical greening facade is aerial roots plant, vines and also climbing plants. The support structure is used for the plant to be able to climb or cascade down the structure.

According to (Sunakorn and Yimprayoon, 2011) vertical garden or green façade are also becoming popular landscape design for home and building. It is widely known that plant absorb heat and light from the sun for photosynthesis process and the best solution to improve the air quality in a certain places since it absorb the carbon dioxide during the day. Based on these criteria, we can conclude that the vertical greening system can reduce the heat and temperature and also improve the air quality in a building.

Lastly, based on the research by the National University of Singapore, the electricity can be reduced by 5% if the temperature of a building decreased by 1°C. This strongly supports the evidence prior to a research by (Sheweka and Mohamed, 2012); vertical greening system can reduce the temperature in a building by 2 degrees during the day and 0.4 degrees at night.

1.1. Problem statement

Most of electricity is used to provide a thermally and visually comfortable built-environment through air-conditioning and artificial lighting. Earlier studies by Goulding et al. (1992) and Krarti (2000), on energy audits and surveys of commercial premises revealed that air-conditioning and artificial lighting account for, respectively, 40–60% and 20–30% of total electricity use. One of the ways to reduce the energy used is through the implementation of passive design approach. The passive design approach is where the heating and cooling system of the building is provided without any means of mechanical energy use whereas, the bioclimatic design is the application of climate study into the design and building's technology mainly to regulate the heat transfer. Therefore, the combination of these two approaches is essential in promoting an energy saving building as well as ensuring thermal comfort for the building's occupant.

In designing a building based on the bioclimatic approach, the most important part of the building is the skin or the facade. It acts as the control medium of any forces that passes the building. Therefore, the design of the skin or envelope of an office building plays a vital role in maintaining the thermal comfort of the building's occupant from the climate condition. Many projects using the vertical greening system as facade can be seen across the world. However, these designs are not making the full use and benefits of the vertical garden itself. For example in Jakarta, most buildings with vertical garden facade are implemented mainly because of its aesthetic value. This is due to the lack of research concerning the thermal effect of vertical garden and the exact percentage of temperature reduction.

1.2. Purpose of study

The aim of this research is to determine the temperature and the humidity in an office building that use vertical greening system thus proving that this method can be best implemented in tropical climate countries. By observing the temperature differences in both office and the humidity percentage in a building, the effectiveness of vertical greening facade can be obtained. This investigation was done by recording the temperature in both office (one with vertical greening façade and one not using the vertical greening façade system) from the same location during the day and observing the energy used by both buildings during the working hour period.

1.3. Aims and objectives of research

This research was carried to evaluate the percentage of temperature reduction of two building samples, one with "vertical greening" and one without. The aim of the study is to investigate whether there are any differences in temperature and humidity in both office buildings during the day. The objectives of this research are listed below.

- To obtain the temperature and humidity differences in both offices.

- To determine the effectiveness of vertical greening façade system.

2. Literature review

2.1. Thermal comfort

The essential principle to achieve an adequate environmental condition is by accommodating the building's occupant with satisfactory thermal condition. According to British Standard BS EN ISO 7730 (2005), thermal comfort is the state where the person's mind is satisfied with the current thermal condition in their surroundings. In short, it is when a person's brain stimulates the feeling of either too hot or too cold.

2.1.1. Factors affecting thermal comfort in working area

The term thermal comfort is hard to define since it depends on certain criteria and varies according to the human body. However, the factors affecting thermal comfort in workplace can be divided into two main categories, environmental factors, and personal factors (McMullan, 1998).

2.1.1.1. Environmental factors

- Air temperatures
- Radiant temperatures
- Air velocity
- Humidity

2.1.1.2. Personal factors

- Clothing insulation
- Metabolic rate

The environmental factor is where the thermal condition is taken into account during the thermal comfort evaluation. This factor can be obtained using certain apparatus and measurement. However, the personal factors are difficult to measure since the human psychology is different. This claim can be supported by McMullan (1998), whereby, the occupants hardly come to terms that the current internal environment in their offices is good enough.

2.2. Tropical climate

A tropical climate is a climate in the equatorial or tropical zone. Among the countries that fall into this tropical climate zone are Malaysia, Indonesia, Singapore and Philippines. These countries will not experience the winter season and most likely to have high temperature (25°C and above) throughout the whole year.

2.2.1. Building characteristics in tropical climate

According to Nedhal et al. (2013), the tropical climate is considered as one of the most difficult climates being implemented into the design. The high temperature and humidity all year round result in the exceeding temperature of summertime comfort. According to ASHRAE (2013), the indoor temperature that is suitable during summertime to achieve thermal comfort is 26°C. However, this temperature limit is can no longer be applied in tropical climate countries. In order to regulate the high temperature and humidity to achieve thermal comfort, there are many strategies that can be taken.

For tropical climate, the building design should focus more on controlling the amount of heat transition and ventilation. In short, it is where the heat in a building is rejected while the light and cool air is admitted.

The building characteristic in tropical climate countries is based on several factors:

- Orientation
- Openings

2.2.1.1. Orientation

Based on the research conducted in Penang, Malaysia by Syed Fadzil et al. (2004), the orientation of the building in tropical climate with the lowest amount of sun penetrates into the building is at the bay with orientation of 0° whereas, the highest amount of sunlight that enters the building is at the bay of orientation of 240°. The orientation of the building is important in order to reduce the temperature of a building and to save energy used to maintain thermal comfort. Approximately 43% of energy can be reduced if the building is designed in the right orientation.

2.2.1.2. Openings

The openings in a tropical climate building should be as large as possible to allow the cross-ventilation to occur.

2.3. Vertical garden

There are two types of vertical garden. One type of vertical garden is green façade, and the other one is the living wall. People mistook that the vertical greening facade system or living walls as the green facade. Both types of vertical garden may appear the same, but the systems differ.

2.3.1. Green facade

The green façade wall is a type of vertical greening system where the climbing plants grow on buildings (Hunter, et al, 2014). As a medium for the plants to grow, the soil is put on the bottom of the wall or sometimes at the top. This method can takes up to 3-5 years for the plants to fully grow and eventually cover the whole façade. The common type of climbing plants that are used in this system is the English Ivy. However, there is disadvantage when using this type of plant. The strong root of an English Ivy will cause the structure to damage and become more difficult to remove it from the façade later.

2.3.2. Living walls

The living walls consist of more than one type of plants. Using this method, groundcover plants are made possible to be planted vertically on the wall surface. It is made up of planted or vegetated modular structures that are of plastics, metal, or other materials that are connected vertically to a structural frame. This type of the vertical garden usually needs more maintenance compared to another system since it has to support a great range of plant species. The system of living walls is different according to the design and functions.

2.3.2.1. Modular living walls (green screen)

A modular living wall is inspired by the system of a green roof that uses modules as a medium to support the growth of plants. In this system, the plant is supported by multiples panels that are of square and rectangular shapes. Each panel consists of growing medium that contains different soil and nutrients composition depending on the types of plant used. The irrigation for this system is usually placed on top of the modules to distribute the water through the growing media using gravity pulls.

2.3.2.2. Vegetated mat wall

The 'Mur Vegetal' is a unique form of green facade system that is engineered by the French botanist, Patrick Blanc. In this system, the plant is supported by two layers of synthetic fabric with pockets. This fabric walls are later connected to a larger frame located on top of the wall surface layered with waterproof membrane to prevent from any damage to the existing wall due to its high moisture content. Similar to the irrigation system of the modular living walls, water and nutrients are distributed evenly across the fabric using the gravity pulls.



Fig.1. The famous 'Mur Vegetal' by Patrick Blanc

(Source: <http://www.murvegetalpatrickblanc.com/patrick-blanc>)

2.3.2.3. Bio-filtration

This type of green facade system fully uses the benefits of vegetated wall. The basic mechanics of bio-filtration system provides thermal regulation and filters the polluted air outside the building using the fan as the generator mechanism. The irrigation system that provides nutrients and water to the plant is similar to the hydroponic technique of plantation where the water is re-circulated from the nutrients solution tank located on top of the wall system. To support the plant roots and the microbes, two layers of synthetic fabrics are placed on top of the gutter that irrigates the nutrients solution. The function of microbes in the synthetic fabric is to expel the airborne volatile organic compounds (VOC) a hazardous chemical pollutants from the other building materials from entering the building and affect the human health.

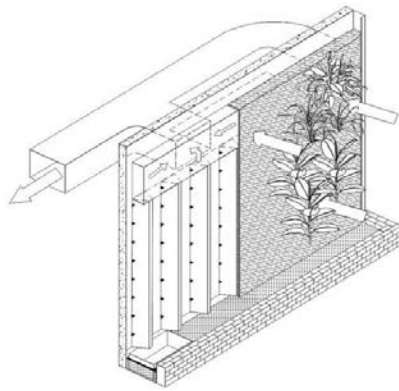


Fig.2. Bio-filtration system

(Source: <http://continuingeducation.construction.com>)

2.4. Factors consideration for choosing the system in an office

In choosing the best system to ensure a successful vertical green facade, few factors should be considered.

2.4.1. Scale

A larger facade of building will need a three-dimensional system or the Modular Trellis Panel System since it requires a lot of maintenance and the needs to cover the building in a short length of time. The use of a two-dimensional system in a large building facade will require a constant maintenance since it does not have a specific

system to channel the water and nutrients. The length of time for the climbing plant to fully cover the building can takes up to 5 to 6 years (Hunter et al., 2014).

2.4.2. Space

In choosing the best system for a vertical garden, the location and size of a building should be taken into account. Considering the fact that the plant will not receive any water supplies in a closed or indoor spaces, therefore, a three-dimensional system is more suitable for a green facade located inside of a building. However, both systems can be applied to the facade if it is located outside of the building.

2.4.3. Concept consideration

A two-dimensional system is more suitable for a design facade for a low-cost green building where it uses 100% vertical garden for facade and shading purpose while three-dimensional system is best implemented in front elevation or any facade design.

2.5. Thermal comfort

Since the thermal comfort cannot be simply measured by its temperature, the humidity level of the office building should also be considered to determine the exact level of thermal comfort in the building. The reason behind this is because the humidity level highly influenced the thermal comfort of a person. If the level of humidity is high, the tendency for a person to sweat is higher. If the air is too dry, or too moist, the level of thermal comfort of a person decreased.

The thermal comfort of the workers varies according to their working desk position. Since the worker whose position is near the windows will receive the highest amount of heat from the temperature outside the office, it is decided to keep the thermometer on the wall that locates the nearest facade windows. The temperature is then recorded every hour from morning to evening. The thermal comfort is achieved when the temperature is not too high (25°C and above) or too low (18°C and below). The comparison of the difference temperature drop in both buildings will be determined by the percentage of temperature calculated based on the data collected.

3. Research methodology

3.1. Research approach

To conduct the study, quantitative measurement is used. The instrument used to record the temperature and humidity of both buildings was the thermometer and hygrometer respectively. The variable in this research is the presence of vertical greening facade system in one of the samples.

3.2. Research design



CIMB Bank Building P.T. Indonesia Greenwall Building

Fig. 3. The location of both sample buildings

The field measurement is conducted on two buildings with the same orientation and at the same time of the day to ensure they received the same amount of solar heat. The research location was held in Jakarta, Indonesia. To obtain both temperature and humidity data, two buildings that are located at the same location were chosen. A company specializing in vertical gardens, PT. Indonesia Greenwall will be the location where the humidity and temperature data with the presence of vertical garden is taken while the building without the presence of green facade is represented by the CIMB building located besides the PT. Indonesia Greenwall building (see Fig. 3.).



Fig. 4. Panoramic view of both buildings

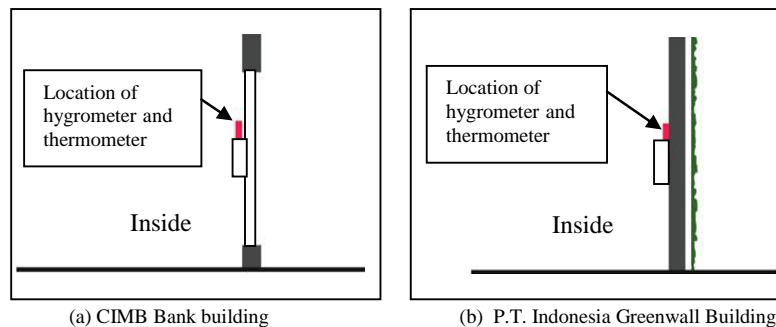


Fig. 5. Typical section of the sample walls

Table 1. The table used to record the temperature and humidity of both buildings

Time	Temperature (°c)		Humidity (%)	
	Indoor	Outdoor	Indoor	Outdoor
8.00 a.m.				
9.00 a.m.				
10.00 a.m.				
11.00 a.m.				
12.00 p.m.				
1.00 p.m.				
2.00 p.m.				
3.00 p.m.				
4.00 p.m.				
5.00.p.m.				

The humidity and temperature of indoor and outdoor of both building is measured hourly form 8.00 am to 5.00 pm using the hygrometer and thermometer respectively. Fig.5. shows the placement of the hygrometer and thermometer in both buildings during the research.

4. Data analysis and findings

4.1. Differences in outdoor and inside temperature of building without the vertical greening

Based on the graph Fig. 6a, the minimum temperature recorded in both indoor and outdoor of the CIMB building is at 9.00 am with the temperature of 28.5°C indoor and 28.7°C outside. Subsequently, the maximum temperature recorded was at 10.00 am The maximum temperature inside the building was 33.45°C whereas the maximum outside temperature outside the building was 35.3°C. It can be concluded that the difference between the temperature inside and outside of the building was comparatively low. This was probably due to the low efficiency of the facade used and could not regulate the heat that enters into the building. There were also other factors that may affect the temperature result.

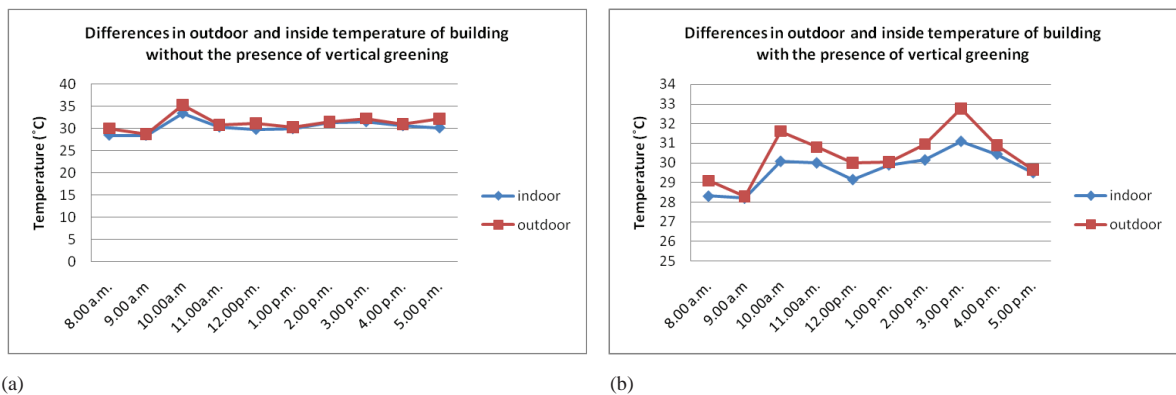


Fig. 6. Differences in outdoor and inside temperature of building

4.2. Differences in outdoor and inside temperature of building with vertical greening

Fig. 6b shows that the office building with the presence of vertical greening façade reached its peak temperature of both inside and outside at 3.00 pm. The maximum temperature recorded inside the building is 31.1°C while the maximum temperature recorded outside the building is 32.75°C.

The minimum temperature recorded is at 9.00 am with the temperature inside the office building is 28.2°C and 28.3°C for the temperature outside. Due to the rain that occurred at 9.00 am the temperature in both office buildings appeared to have the same minimum temperature.

4.3. Comparison of temperature reduction percentage in both buildings

Fig. 7. indicates that the office building with the vertical greening facade clearly have higher amount of temperature reduction compared to the office building without vertical greening facade. The maximum percentage of temperature recorded at 10.00 am is 0.29% higher than the temperature in the building without vertical greening facade. The graph indicates that the highest percentage of temperature reduction in building with vertical garden facade can achieve up to 10% while the minimum percentage of temperature reduction it can achieve is 0.99%. As for the building without vertical garden, the maximum percentage of temperature reduction is 6.21%, and the minimum percentage of temperature reduction is 0.97%. Both building facades can reduce the indoor temperature, but the facade with the vertical greening is more effective as it can reduce the indoor temperature by 3.79%.

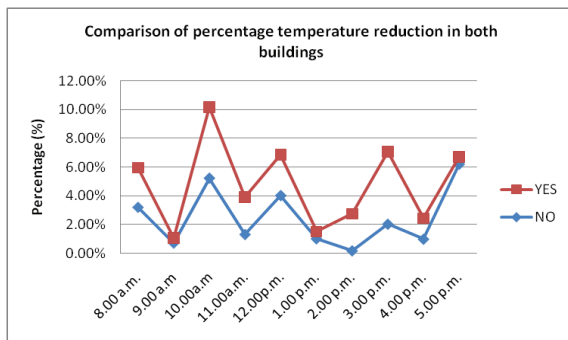


Fig. 7. Comparison of temperature reduction in both buildings

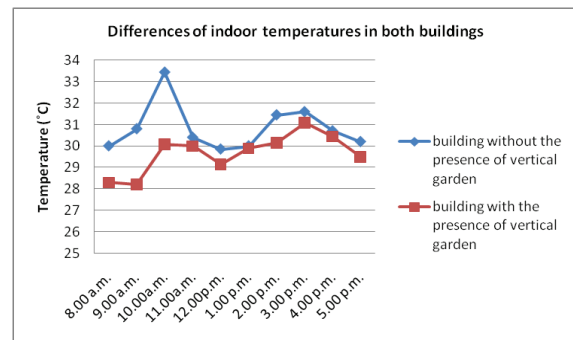


Fig. 8. Differences of indoor temperatures in both buildings

4.4. Differences of indoor temperature in both buildings

Fig. 8. shows the differences of the indoor temperature of both façades. There were large differences between the two indoor temperatures recorded that indicates that the indoor temperature of the building with the green facade is lower than the building without the green facade. From 9.00 am to 10.00 am the graph of the blue line increased dramatically and lost high amount of temperature after 10.00 am. However, the graph of the red line rose slowly and cooled down constantly after 10.00 am. Though the indoor temperature of the building without the presence of green facade reduced easily, the temperature of the building with the green facade remained lower.

4.5. Differences of temperature on the outside of both buildings

Fig. 9. shows that the highest outside temperature recorded for both buildings was at 10.00 am while the minimum outside temperature recorded was at 9.00 am. All in all, there is not much difference between the outside temperatures of both buildings. However, the temperature of the blue line that indicates the building without the vertical greening facade appeared to be higher than the outside temperature of the building with green facade.

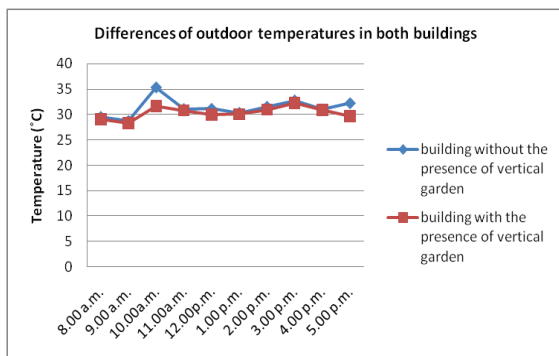


Fig. 9. Differences of outdoor temperature in both buildings

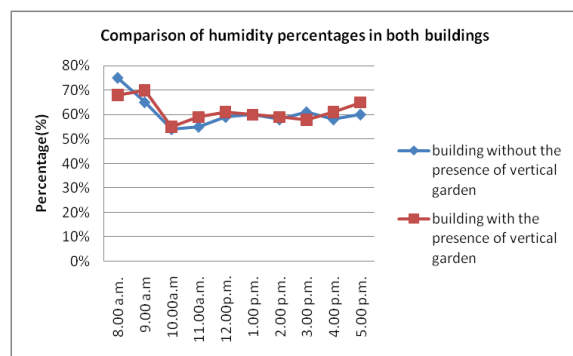


Fig. 10. Comparison of humidity percentages in both buildings

4.6. Comparison of humidity percentages of both buildings

Both data in Figure 10 have a similar pattern starting from 9.00 am. Subsequently, both data appears to increase gradually until 12.00 pm. After 12.00 pm, the graph started to slightly decline until 3.00 pm and rise again. Despite the similar pattern in both buildings data, the percentage of humidity in building with vertical greening facade is relatively lower than the building without the vertical garden.

5. Conclusion and recommendation

Based on the data analyzed, the implementation of vertical greening facade on an office building clearly reduces the temperature and humidity of a building. It can be concluded that the building with vertical greening facade has a higher ability to regulate the temperature than the building without the vertical greening facade. However, in terms of the ability, the building with green facade (P.T. Indonesia Greenwall) has higher ability to reduce the temperature.

The humidity percentage in the building without the presence of vegetation as facade shows a negative result. The percentage of humidity throughout the day is quite high compared to the building with the vertical greening facade. Since the amount of thermal comfort affects the level of thermal comfort of a person, the CIMB Office building shows that the level of thermal comfort is slightly lower compared to the PT. Indonesia Greenwall Office.

Therefore, this study has proved that vertical greening façade do effectively acts as a passive approach towards sustainable building design in the urban area of tropical climate countries. However, the level of effectiveness depends so much on the type of green wall design and the orientation of the façade towards the intense heat of the sun.

5.1. Recommendations

The study has shown the promising benefits of vertical greening system on an office building in the tropical climate condition. In order to inaugurate these results, the study on the effects of vertical garden should be continued further with the actual green facade building that uses 100% of its advantages. This will encourage more possible explorations on the actual benefits of vertical greening system, thus enhancing the use of vertical garden in offices.

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